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by

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The Application of Correlation Matching Technique in Image Guidance

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Abstract: This paper will discuss the application of the correlation matching technique in image guidance. Through the analysis and study of the correlation algorithm, we develop the concise algorithm and realization method to meet the needs of real time processing. The algorithm is tested by the infrared image data of the target.

Key words: MAD, coarse matching, fine matching, FPGA realization

1. Introduction

In pace with the application and advancement of image processing technique, correlation matching becomes one of the key techniques in the area of information processing. The application areas include (1) terrain contour matching and map matching guidance system of missiles, such as the Tomahawk cruise missile of the U. S. It is obvious that this kind of missile has a very high guidance accuracy. (2) satellite aviation guidance and satellite navigation guidance; (3) terminal guidance and homing guidance of weapon systems. (4) all kinds of target image tracking and target aiming devices, etc. This paper will emphasize the accurate identification of the aiming point which is applied to the missile's terminal guidance system.

2. The concept of correlation matching

The conventional meaning of correlation matching is:

At first, using satellites or reconnaissance planes, we can get a series of topographic feature images in the pre-determined flight path of the

aircraft, then store those images in the memory of the aircraft computer. Those images are called reference images. When the aircraft flies over every pre-determined position, the sensor in the aircraft will detect the real time topographic feature image (this image is called the real time image). Thus, we can compare the real time image with the previously stored reference image and get the deviation of the aircraft off the pre-determined flight path, then output the signal which indicates the deviation.

When correlation matching is applied to the terminal guidance and homing guidance of the weapon system, we can get a reference image (also called "template") and a real time image (also called searching area) by using the same sensor at different time. This is a special case of correlation matching.

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Terminalguidance and homing guidance are considered near target correlation matching. The target is usually fill up or exceeds the view area. At this time, we can not get the correct aiming point, if a geometry algorithm or other methods are utilized. It is necessary to adopt image correlation matching to resolve this problem.

The frame frequency of the imaging sensor is between 25 Hz and 100 Hz. It is very smooth between different frames. Thus a small area around the aiming point in the last image frame that has been identified can be used as the template (reference image), an area in current image frame is used as the searching area (real time image). The matching point that we get after correlation matching computation is the aiming point in this image frame. Repeating this process will lead the aircraft to the target.

3. Algorithm Analysis

We assume that the size of the image from the imaging sensor is K * L, the aiming point that identified in last image frame is (x0, y0). We can select a small area around the aiming point as the template, the

template size is m * n, and we store the template data into template memory. After we get the current image frame, we select an area around (x0, y0) as search area, with the size M * N, and store the search area image data into the search memory. Because the terminal guidance system detected stablized tracking (good lock-on), usually (x0, y0) is right at the center of the viewing field. We select the center of those areas as (x0, y0), select m:M:K = 1:2:4 and n:N:L = 1:2:4 to make sure a good correlation matching results.

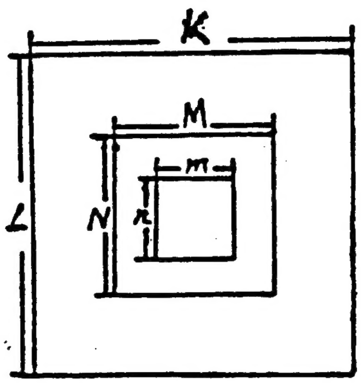

Figure 1

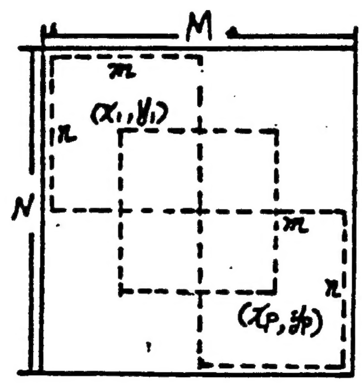

Figure 2

Correlation matching is to test the degree of similarity between the image data of the template and search area, the greater the correlation. The greater the similarity.

There are many typical algorithms in correlation matching, such as Absolute Difference algorithm (AD algorithm), Mean Absolute Difference algorithm (MAD algorithm), Modulo-2 Sum algorithm (XOR algorithm), Squared Difference algorithm (SD algorithm), Mean Squared Difference algorithm (MSD algorithm) and so on. Basically, these algorithms have the minimum value property. Only when the two images match will the measure of correlation reach the minimum value.

Currently the correlation matching has matured for practical application. To meet the requirement for easy implementation in engineering, the algorithm ought to be simple, accurate, speedy. So the MAD (mean absolute difference) algorithm is the best. The point (x, y) which has the minimum value of MAD,

confirms that the real time image resembles the reference image most, this point is also the best aiming point.

We move the m * n data matrix and M * N data matrix point by point to process MAD computing:

(xi, yi)   (i = 1 -- P)   P = (M-m+1) x (N-n+1);

We need to perform MAD computation P times in all.

We need to do m * n subtractions corresponding to each point (xi, yi) and add up the absolute value of these differences which require m * n absolute value additions. After computing, the result value is the MAD value corresponding to the point (xi, yi). We select the point which has the minimum MAD value as the aiming point.

Affected by noise, interference, and the change of grey scale of the target between different frames and other factors, the matching point that is computed by the correlation matching algorithm is slightly different from real matching position. Acting as the aiming point of terminal guidance, the matching point must be selected to avoid a guidance error that is caused by matching deviation. So, it is necessary to set a threshold: only when the MAD value is less than the threshold, can the matching point be used as the aiming point. Otherwise, the aiming point of last frame should be kept. This method is practical and necessary in situations where the aircraft is very close to the target.

Another situation that should be emphasized is that, whenever the target is partially obscured due to the interference, if we modify the template, the aiming point will be gradually moved out of the target area by the defilade as the correlation matching is processing. To avoid that, the template is modified only when the correlation matching is larger than the revision threshold, instead of frame by frame. This is shown in Fig. 3.

1. Data bus

2. Template memory

3. Address mapping

4. Searching area memory

5. MAD computation

6. Matching point selection

7.

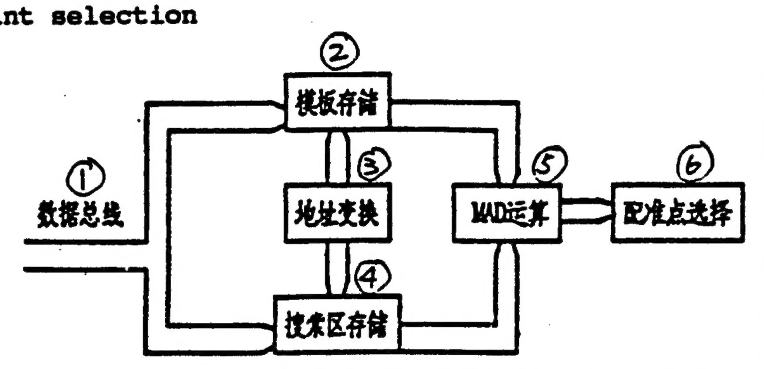

Figure 3

4. The results of computer processing

To test if the image correlation matching is practical, we programmed a C program to process the correlation matching. We used these programs to process the infrared image of an airplane. The image data is saved in 8 bit data format. First two continuous frames of an airplane image are acquired, then a small part of the center

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area in the first frame's plane body is selected as the template, and the center area in the second frame is selected as searching area. The processing procedure is divided into two parts, one is coarse matching (large distance between the matching points) and another part is fine matching (small distance between the matching points). The results we obtained are satisfactory. The maximum matching error in the coarse matching is $2\sqrt{2}$ pixel distance and in the fine part is $\sqrt{2}$ pixel distance.

Fig. 4 is the flow chart of the C program, and Fig. 5 shows the computer processing results.

5 . Conclusions

By analyzing the algorithm and processing the software, it is found that the correlation matching procedure is computationally very expensive. But this image processing method is strongly required for real-time operation. That means a simpler, precise algorithm is needed. At the same time, the huge hardware circuits are a difficulty for application.

To improve the computational speed, the correlation matching procedure can be divided into two stages: coarse matching stage and fine matching stage. The purpose of the coarse matching is to quickly and precisely find a rough matching point which is called the coarse matching point. After that, the correlation matching is computed point by point in the area (i.e. 3 * 3 or 4 * 4) around the coarse matching point found before, in this way, the matching point can be found very fast.

Thus, in the coarse matching stage (assume the distance between matching point is k), we need only $Q = ((M - m) / k + 1) \times (N - n) / k + 1)$ MAD computations .

In the fine matching stage (assume searching in the s * t array) , only $R = s * t$ MAD computations are needed. The addition of them is :

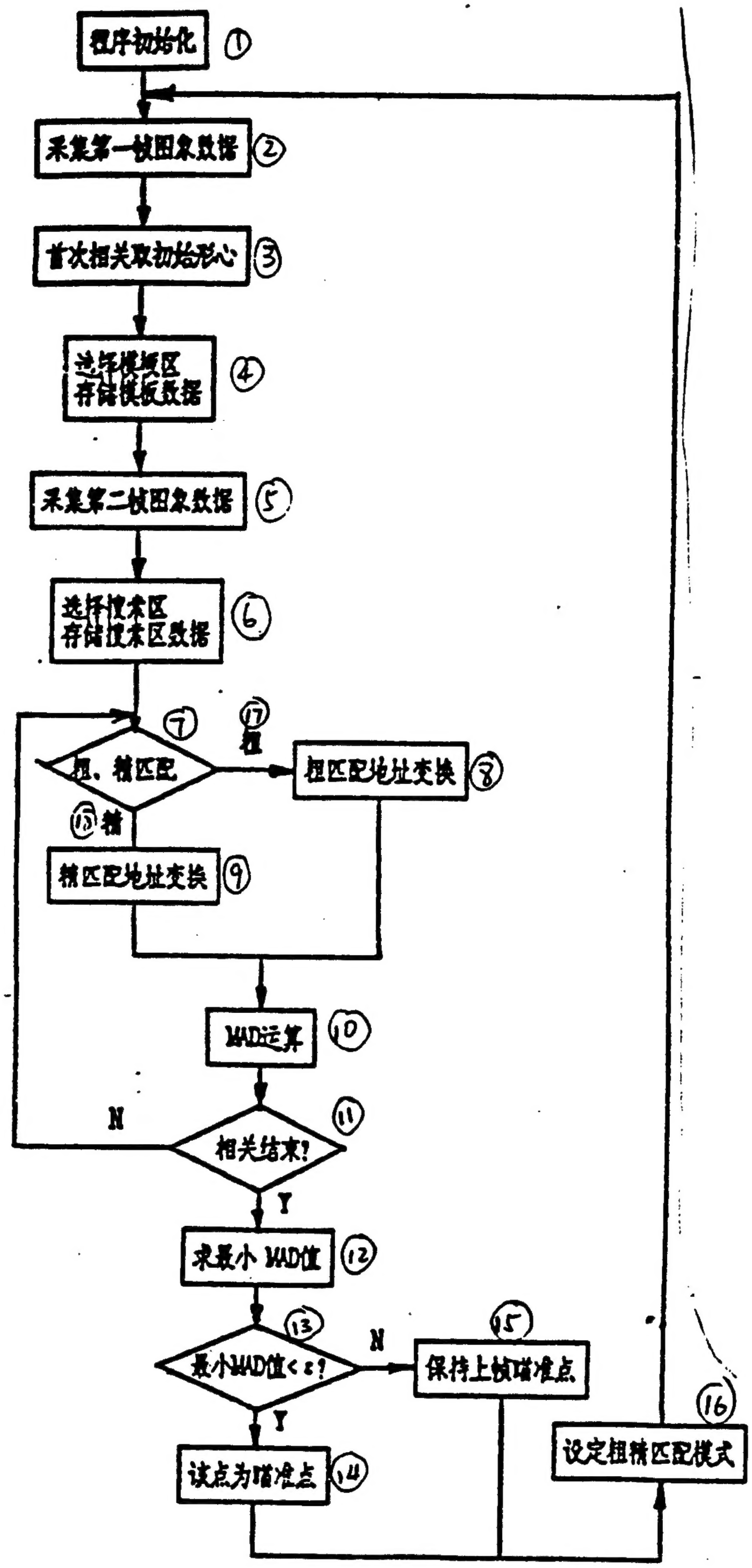
$$Q+R = ((M-m)/k+1) \times ((N-n)/k+1) + s \times t << P = (M-m+1) \times (N-n+1)$$

It is obvious that the computations are reduced greatly.

Because the coarse matching also has a good matching accuracy rate, we can improve the correlation processing speed and only slightly affect on the matching accuracy by using the coarse and fine combined matching method.

In hardware circuits we can use a FPGA on-site large scale programmable gate array. The packing of FPGA devices usually are square shaped with 68 or 84 pins. It has very strong digital logic. processing ability. This can greatly reduce the hardware circuits scale and still satisfy the specifications of any real system.

Due to the limitation of article length, I cannott go into more detail. I appreciate any suggestions or criticism about this article.



程序初始化 ①
采集第一帧图象数据 ②
首次相关取初始形心 ③
选择模板区
存储模板数据 ④
采集第二帧图象数据 ⑤
选择搜索区
存储搜索区数据 ⑥
粗、精匹配 ⑦
⑰ 粗
粗匹配地址变换 ⑧
⑱ 精
精匹配地址变换 ⑨
MAD运算 ⑩
N
相关结束? ⑪
Y
求最小MAD值 ⑫
最小MAD值<ε? ⑬
N
保持上帧瞄准点 ⑮
Y
该点为瞄准点 ⑭
设定粗精匹配模式 ⑯

Fig. 4:

1. Program initialization

2. Compile data for the first image frame

3. Initialize the points of the first correlation

4. Select template area and save template data

5. Compile data for the second image frame

6. Select searching area and save searching area data

7. Coarse or fine matching?

8. update coarse matching address

9. update fine matching address

10. MAD computation

11. End correlating?

12. Find the minimum value of MAD

13. Is this the minimum value of MAD?

14. This is the matching point

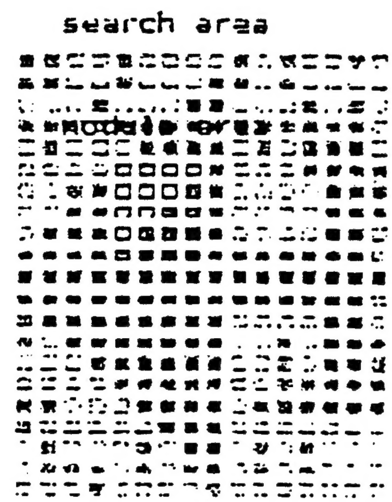
15. Keep the matching point of the previous frame

16. Set the model of coarse and fine matching

17. Coarse

18. Fine

MAD point:
match step= 4
match accuracy: rough
module px & py: 28 ... 26
search px & py: 28 ... 24
dlt px & py: 0 ... -2



MAD point:
match step= 1
match accuracy: refine
module px & py: 28 ... 26
search px & py: 28 ... 26
dlt px & py: 0 ... 0

Figure 5